

The present invention relates to a lighting means compatible with a light intensifier night vision imaging system.

Recent years have seen the emergence in the market of aeronautical equipment for night vision systems to facilitate night flying and overcome the lack of the sensitivity of the human eye to light in the infrared range, namely at wavelengths of more than about 770 nm. These systems, generally known as NVIS (night vision imaging systems) are highly sensitive to infrared radiation up to wavelengths of about 900 nm. They usually take the form of goggles comprising two light intensifiers, each intensifier being comparable to a miniature video camera delivering an electronic image of the external environment. Even in the greatest darkness, a night imaging system delivers a clear, high-contrast monochromatic image of the external environment.

Very briefly, it may be recalled with reference to Figure 1 that a light intensifier comprises a vacuum tube 2 having a photocathode 3 at its first end that converts the photons from the image received on its external face into an electron beam whose density and distribution are a function of the image. The electron beam is sent to a

phosphor screen 4 positioned at the other end of the tube 2 by means of an amplifier plate 5. The amplifier plate 5 has numerous microchannels 6 covered with a secondary high-emission coating whose role is to greatly increase the number of electrons sent by the photocathode 3. The amplifier plate is driven by a circuit 7 called an "automatic gain control" circuit. This circuit 7 is a feedback circuit that optimizes the gain, namely the intensifying level, as a function of the ambient luminosity and gives a result comparable to the closing or opening of a diaphragm. Without this protection circuit, an increase in the ambient light energy in the band of sensitivity of the photocathode would prompt an immediate increase in the flow of electrons and would lower the sensitivity and resolution. The circuit 7 prompts the total extinction of the intensifier tube when there is a sharp variation in the radiant energy.

As light intensifiers have undergone various improvements since their appearance, there are now two types of light intensifiers using concurrent technologies on the market. These are GEN2 (second generation) and GEN3 (third generation) intensifiers. GEN3 tubes have a gallium arsenide photocathode and can be distinguished by their very high sensitivity to radiant energy, namely a sensitivity of about 1200 to 1800 $\mu\text{A}/\text{lm}$ depending on the models, and a fairly selective passband ranging from 600 nm (at the borderline limit between the yellow and the red wavelengths) to 900 nm. The GEN2 tubes have a tri-alkaline photocathode with lower sensitivity, of about 500 to 800 $\mu\text{A}/\text{lm}$, and a wider passband ranging from 400 to 900 nm and covering the visible spectrum. For a clearer picture, the curves 10 and 11 of Figure 2 respectively show the gain G of the tubes GEN2 a GEN3 as a function of the wavelength λ . Despite their lower sensitivity, tri-alkaline photocathodes have a better

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- secondly, the lighting of the aircraft should not disturb the intensifier tubes by giving rise to parasitic halos or ghost images due to the reflection of illuminated objects on the windows of the cockpit.

Furthermore, the risks of interference between the light sources of the aircraft and the night vision
35 goggles are eliminated by a retrofitting of the aircraft

Thus, in practice, the retrofit of an aircraft illumination system consists in encapsulating the incandescent white lamps with lowpass attenuator filters and replacing the other white incandescent white lamps by light-emitting diodes or light-emitting panels scattering a narrow and green colored light also called an "aviation green" centered on the 555 nm. In general, the white incandescent lamps to be encapsulated are the yellow, orange and red lamps of warning indicators and alarm indicators. The incandescent white lamps need to be replaced by green light-emitting diodes and are for example green indicator lamps, used for the lighting of the instrument panel as well as backlighting lamps which, by transparency, reveal luminous graphic characters on an instrument panel. Finally, the lights used for ambient

illumination are generally replaced by green light-emitting panels with which a mechanical scattering device with swiveling shutters is associated.

5 This kind of retrofitting of lighting means for an aircraft has various drawbacks. Firstly, it gives a greenish ambient light that very substantially attenuates the readability of the panel instruments and dilutes the colors. Thus, for example, the white or yellow, orange and red paint on the panel instrument packs (used for
10 example to define and demarcate the operating modes of an engine) are respectively seen as green, light brown or dark brown. Again, the green lighting makes it difficult and tiresome to read the navigation maps. Furthermore, the red alarm indicators and those that have a red component like the yellow and orange indicators have
15 mediocre luminosity and unsatisfactory coloring owing to the high absorption of the attenuator filter. Finally, yet another drawback of a retrofit operation of this kind is the high cost of the attenuator filters.

20 In the prior art, these drawbacks are considered to be inherent because it is sought to reconcile the infrared vision of the external environment with the natural vision of the panel instruments. It is furthermore considered that the "aviation green" color at
25 555 nm is the ideal color to reconcile the various requirements. Firstly, this green is distant enough from the red not to disturb the night vision system. Secondly, the green light-emitting diodes (as well as the green light-emitting panels) are "clean" and emit practically
30 no energy in the red band, namely beyond 600 nm. Finally, green is the color where the sensitivity of the human eye is the maximum, so that it is preferred to the blue. More specifically, apart from its low sensitivity in the blue, the human eye has high remanence in the blue. This is
35 considered to be incompatible with night vision.

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Despite these various considerations which have led those skilled in the art to make the technological choices just described, the present invention is based on a surprising observation whose significance runs counter to prevailing assumptions and standards. According to this observation, a white color emitted by a light source working by electroluminescence in no way disturbs the presently known night vision systems, whether of the GEN2 type or of the GEN3 type. More specifically, the white light-emitting diodes as well as the white light-emitting panels available in the market of luminous components, normally intended for large-scale consumer applications, emit radiation that does not activate the automatic gain control circuit of a night vision system and does not even need to be filtered in the critical band of the red to offer these advantages. A non-disturbing radiation of this type however has a red component, but one with a low energy component. Here below, we shall see the explanations that may be given for this very advantageous compatibility of the white light-emitting sources with light intensifier systems. In any case, the discovery made by the Applicant has a considerable practical consequence for the field of aeronautics which is that it can offer aircraft pilots viewing comfort comparable to that of daylight while enabling the infrared display of the external environment by means of a light intensifier system without any risk of the untimely activation of an automatic gain control circuit.

Thus, the present invention proposes a lighting means compatible with a light intensifier night vision system comprising at least one light-emitting source of a white light with low radiant energy in the red wavelengths band.

The invention is made with a lighting means compatible with a light intensifier night imaging vision

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According to one embodiment, the light source is a white light-emitting diode.

For example, the light-emitting diode may be mounted on a screw-in or bayonet type socket. It may also be used instead of the standard incandescent lamp.

To light up the graphics of an instruments panel,
5 the light-emitting diode is placed behind an opaque panel
comprising transparent zones that form graphic
characters.

To form a colored indicator, especially a green, yellow or red indicator, the light-emitting diode is covered with a colored hood that is not filtered in the red wavelengths band.

For ambient light, especially in a cockpit or an instruments panel, the lighting means according to the invention may include a ramp of white light-emitting diodes. The lighting means may also include a white light-emitting panel.

The present invention also relates to a means of lighting, especially for position indicators, landing lights, anti-collision lights or flight training lights in an aircraft comprising a plurality of light-emitting diodes arranged on a printed circuit.

Advantageously, the printed circuit is fixedly joined to a screw-in or bayonet type socket.

Advantageously, the polychromatic white light-emitting source is used with a light intensifier night vision imaging system with no filtering of the night imaging system in the visible wavelength bands.

The present invention also relates to an aircraft including a light-emitting means of the type described here above.

The present invention also relates to a lighting system comprising means of lighting in the visible range, means of lighting in the infrared range and switching means to make a choice between a lighting position in the visible range and a lighting position in the infrared

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view of a light intensifier tube,

- Figure 2 described here above shows the gain curves of two standard light intensifier tubes,

- Figure 3 shows the curves of the relative intensity as a function of the wavelength of the light emitted by a green light-emitting diode and a white light-emitting diode,

- Figure 4 illustrates an application according to the invention of a white light-emitting diode,

- Figures 5A and 5B respectively show a top view and a sectional view of another application, according to the invention, of a white light-emitting diode,

- Figure 6 shows a lip light and illustrates yet another application, according to the invention, of a white light-emitting diode,

- Figure 7 shows an element of the lip light of Figure 6,

- Figure 8 shows a graph of chrominance of the human eye that gives a schematic view of the spectral dominants of a white light-emitting source implemented according to the invention, and

- Figure 9 shows the curves of absolute intensity as a function of the wavelength of the light emitted by a green light-emitting diode and by a white light-emitting diode having comparable luminous power values.

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25 The present invention is based on the observation that the light emitted by the commercially available sources known as white light-emitting sources in no way disturbs the presently known night vision systems, whether of the GEN2 type or of the GEN3 type.

30 The term "white light-emitting sources" designates white light-emitting diodes as well as the white light-emitting panels available in the market of luminous components. These components are designed normally for large-scale consumer applications, for example to
35 indicate emergency exits or make illuminated

advertisement hoardings etc. They are used because they consume little power and are long-lived.

5 Figure 3 shows a curve 15 corresponding to the relative intensity, as a function of the wavelength, of the light emitted by a white light-emitting diode referenced T1 WHITE LED LE-W31N marketed by the Swiss company SLOAN. This low-voltage diode working at less than 3.6 V/20 mA has the advantage of a high output of 5 lm/W which makes it compatible with the lighting of instrument panels. At the side of the curve 15, there is also a curve 16 corresponding to the relative intensity of a green light-emitting diode used in conventionally in aeronautics. The white diode was tested by the Applicant with a GEN3 type intensifier system marketed under the reference OB56 by the French firm SFIM as well as with a GEN2 intensifier system marketed under the reference SUPERGEN by the firm PHILIPS. In an surprising way, the indirect lighting tests (ambient light) have shown that the white light-emitting diode sends out radiation that does not create any halo or ghost image in the night vision system and does not activate the automatic gain control circuit. These highly advantageous results have been obtained without any filtering of the white light or filtering of the night vision system. Even more surprisingly, direct lighting tests (night vision goggles oriented directly towards the light source) have shown that the automatic gain control system of a night vision system is more sensitive to the green light-emitting diodes used in the prior art (curve 16) than to the white light-emitting diodes discovered by the Applicant (curve 15).

25 This surprising result has several aspects. Firstly, as we have seen in Figure 3, the spectrum of wavelengths of the white light-emitting diode extends up to the red band. Furthermore, for identical light intensity (power

emitted per unit of solid angle), the white diode delivers illumination (power received per unit of surface area) that is significantly higher than the standard green diode (at least two to three times higher). This means that it might have been expected that there would have been an even greater incompatibility of the white diodes with the light intensifier system.

The Applicant, without vouching for the hypothesis, has put forward an explanation according to which the energy emitted by the white light-emitting diode in the critical band of the red is very low and represents only 5 to 7% of the total light energy (the area of the curve 15), which is highly centered on the violet/blue band and on the green band where there are two peaks of intensity 15-1, 15-2. It furthermore seems that this total distribution of the energy between the violet/blue band and the green band contributes to the result obtained, with the mean energy finally being at a greater distance from the red than the energy sent by a green light-emitting diode.

Furthermore, the Applicant has made certain of the stability (or repeatability) of the result obtained and has tested other white light-emitting sources manufactured by other manufacturers which also give excellent results. In particular, the Applicant has tested white light-emitting diodes commercially distributed under the reference LED WHITE PLANE by the firm MICHIA as well as white light-emitting panels for large-scale consumer uses commercially distributed under the reference COLOR WHITE by the British firm DANIELSON which, in its catalogue, also proposes green light-emitting panels for aeronautics under the reference AVIATION GREEN.

However, it is up to those skilled in the art, by simple practical tests, to ascertain that such and such a

white light-emitting diode available in the market gives the results of the invention. In principle, it is believed by the Applicant that this result should be achieved inasmuch as the radiant energy emitted in the critical band of the wavelengths of the red is low. The influence of this distribution of energy between the violet/blue bands and the green/yellow bands is the object of the physical explanations given here below as an indication.

In Figure 2, the curves 10 and 11 show certain characteristics of reception phenomena in light intensifier night vision systems of the GEN2 and GEN3 types respectively.

The curve 10 shows that a GEN2 type night vision has maximum sensitivity in the red band.

The sensitivity decreases sharply in the infrared at a wavelength below 900 nm but, on the contrary, it decreases slowly in the visible range up to the violet band.

Dissymmetrical curves of this kind with a sharp threshold at high wavelengths and a long tail towards the short wavelengths are characteristics of reception phenomena in photocathodes. The wavelength threshold corresponds to the energy required from a photon to release an electron of the sensitive element of the photocathode. The slow decrease of sensitivity to the short wavelengths corresponds to the slow reduction of the probability of releasing an electron when the photon has energy that is higher than this required energy.

The curve of sensitivity of the gallium arsenide photocathodes of the GEN3 type night vision systems have the same dissymmetrical shape, with a maximum sensitivity in the infrared at a wavelength of about 900 nm and a mean level of sensitivity that is higher.

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It is noted however that, on the curve 11 of Figure 2, the slow decrease to sensitivity that should appear towards the short wavelengths of the visible range is eliminated owing to a filtering of the visible wavelengths which is usually associated with GEN3 type night vision systems.

Indeed, the filtering of the GEN3 type night vision systems cuts off the transmission of the wavelengths above 600 nm, ranging from the yellow to the ultraviolet so as not to be parasitically affected by the ambient lighting and so as to keep the transmission of the infrared wavelengths and red wavelengths needed for night vision.

Unlike the dissymmetry of the reception spectra, the semiconductor-based light-emitting sources have fairly narrow spectral lines in emission, with a sharp threshold towards the short wavelengths and a more gradual decrease towards the big wavelengths.

Thus, Figure 3 shows that the spectrum 16 of the "green aviation" silicon diodes, which are well known, have an emission peak at a 555 nm wavelength, decreasing sharply towards the shorter wavelengths in the blue range and decreasing more gradually towards the big wavelengths in the orange range.

Surprisingly, the invention shows that when the wavelengths of the tail of emission of the lighting means coincide with the wavelengths of the tail of receptivity of a night vision system, there is no phenomenon of dazzling nor any untimely activation of the automatic gain control of the night vision system.

Indeed, in this common wavelengths band, the low residual intensity of the light source combined with the low residual sensitivity of the night vision system does not reach a threshold sufficient to cause any saturation of the night vision system.

The entire value of the light-emitting sources implemented according to the invention is that it gives white light with emission off-centered towards the violet/blue wavelengths band instead of having
5 monochromatic light centered on the green/yellow wavelengths band as in the prior art.

Even more surprisingly, the white light produced by the light-emitting source implemented according to the invention has a bichromatic-dominant spectrum with only
10 one violet/blue peak of chrominance and a wide range of chrominance going from the green to the orange but without any dominant in the third primary color, red.

Indeed, as can be seen in the graph of chrominance of the human eye of Figure 8, it is enough for a light
15 source to have a high peak of emission with a wavelength of about 430 nm to 490 nm and a medium emission in a wavelengths band stretching from about 520 to 600 nm for the weighting of the light to correspond to a white light for the human eye.

It must be noted that the diode T1 WHITE LED and the plate LED WHITE PLANE referred to here above have colorimetric parameters ($x=0,29$: $y=0,30$ and $x=0,31$: $y=0,32$ respectively) that enter precisely into the range of the white.
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Furthermore, it is known that the human eye has very high sensitivity in the red range and low sensitivity in the blue range so much so that a polychromatic light is perceived as being white when it contains about 5% of red component, 20% of green component and 75% of blue
25 component in proportion of light intensity. The spectral distribution, shown in Figure 3, of the light intensity of the light-emitting source shows that the polychromatic light corresponds substantially to this definition of whiteness.
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Contrary to the prevailing assumptions in the field of night vision according to which it is necessary to avoid blue light which is supposed to desensitize the rods in the eye and thus inhibit night vision, and according to which it is necessary to avoid white light-emitting diodes which would emit too strongly in the red and the infrared wavelengths, the light-emitting source with its spectrum off-centered towards the violet/blue wavelengths, implemented according to the invention, has very good luminosity for the human eye and does not parasitically affect the night vision systems.

Figure 9 again shows that, for equal luminous power, the white light-emitting source with high radiant energy in the violet/blue range has residual energy in the red comparable to that of the "green-aviation" light-emitting diodes of the prior art.

The particular feature of the invention is therefore that it makes use of a light-emitting source with high or very high radiant energy in the violet/blue wavelengths band and high or mean radiant energy in the green/yellow and orange wavelengths bands with low residual energy in the red wavelengths band.

Advantageously, the white light source implemented according to the invention gives very good luminosity for the human eye.

Another advantage of the invention is that it prevents any disturbance in night vision devices, even in direct lighting.

The absence of disturbance also mean that it is possible to envisage the use, without filtering, of GEN3 type night vision systems with white light-emitting sources according to the invention.

Indeed, the Applicant has observed that, after retracting the "minus-blue" filters which are usually fitted into any night vision system using gallium

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arsenide photocathodes, these systems remain compatible with lighting by the white light-emitting sources according to the invention.

In practice, the discovery according to the invention has a consequence of considerable significance, namely the ability to give aircraft pilot visual comfort comparable to that enjoyed in daylight conditions while enabling infrared viewing of the external environment.

Thus, as shown in Figure 4, it is proposed for example that each incandescent lamp 20 of an aircraft should be replaced by one or more white light-emitting diodes 21 mounted on a screw-in or bayonet type socket 22 compatible with the sleeve 23 of the incandescent lamp 20. This change in light source implies a modification of the supply voltage of the lighting system which should be taken to 3.6 V/20 mA.

In general, a white light-emitting diode can be used for the ambient lighting, the lighting of the panel instruments, the making of light indicators and the backlighting of the graphics display panel. These display panels, which are generally made of Plexiglass, are painted black and include paint-free transparent zones that form graphic characters. The white light-emitting source can also give lighting guided in a translucent board of the instruments panel. Also, several white light-emitting diodes may be arranged in a ramp for the lighting of an instruments panel or for ambient lighting. For ambient lighting, it is preferred however to have a white light-emitting panel which offers the advantage of better distribution of light. Finally, the color indicators are preferably made without any addition of attenuating filters. The light-emitting diodes are simply covered with a hood made of colored plastic.

Furthermore, according to one aspect of the
35 invention, it is proposed to combine several white light-

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landing strip) and one or more white light-emitting diodes, herein two diodes 51, used to consult road maps or illuminate the cockpit.

5 It will clearly be seen by those skilled in the art that the present invention is open to various other variants and applications. In general, the present invention can be used to obtain any type of lighting compatible with light intensifier night vision systems. It is clear that the field of application of the
10 invention is not limited to aircraft and can generally be extended to any land-based or sea-based application, especially the beaconing of air strips and runways, the lighting of parking lots, lighting to indicate borders and track center lines, beaconing of obstacles etc.

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